Clean Diesel Technologies, Inc.

A specialty chemical company supplying fuel additives and systems technology that reduce harmful emissions from internal combustion engines while improving fuel economy

CARB – International Diesel Retrofit Advisory Committee

Part I – Performance of FBC Based Systems

February, 2002

Commercial Product Groups

Platinum Plus® Platinum / Cerium Fuel Catalysts

- Performance (Fuel Economy)
- Emissions (No.2D, Jet/Kero, ULSD or Emulsions)
- Aftertreatment (Used With Oxidizers And Filters)

ARIS™ 2000 Urea Injection System For Selective Catalytic Reduction Of NOx

- Packaged Stationary Systems (Commercial)
- Mobile Systems (Prototypes In Field)
- LOE-NOx™ 3200 Urea Based Reagent

What is a Fuel Borne Catalyst? (FBC)

- Organo metallic fuel soluble catalyst
- Typically platinum and/or cerium or iron
- In-use dose rates of 4 - 60 ppm metal in fuel
- Dose rates above 15 ppm can lead to increase in ultrafine metal oxides
- Can reduce engine out soot emissions
- Can reduce soot oxidation temperatures in DPF's by 100-250°C
- USA requires EPA Registration of FBC's for on-highway use
  - Minimum Tier 1 – 1000 hr. engine test
  - Regulated emissions test plus 200 unregulated species
  - Additive emissions, speciation, literature review and risk assessment
- Europe requires VERT, VSET for FBC/DPF
- Several thousand commercial applications worldwide


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Platinum/Cerium(FBC)

- Patented bimetallic platinum/cerium kerosene based solution used at 4-8 ppm metal in fuel
  - Non toxic, non mutagenic, non water soluble
- Reduces engine out PM, HC, CO and improves fuel economy
- Synergistic with DOC
- Improves regeneration performance of uncatalyzed or lightly DPF's
  - Regeneration @ 300 - 350 °C
  - No NO_2 increase
  - Minimum ash
  - Softer regeneration
- No harmful metal emissions, ultrafines, or secondary emissions
- Over 1,000 vehicles in service
- Registered with U.S. EPA for use in on-highway fuel (December 1999)
- Approved under VERT and VSET protocols for use with filters (2000)
- BUWAL approved for filters (2001)
- Submitted to EPA under Voluntary Retrofit
- Planned submittal to CARB (1st Qtr. 2002)


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DPF APPROACHES

"Catalyst-based DPFs use catalyst materials to reduce the temperature at which collected diesel PM oxidizes. The catalyst material can either be directly incorporated into the filter system, or can be added to the fuel as a fuel borne catalyst (FBC-DPF)." CARB-Risk Reduction Plan, October 2000

Technology	Approach
Precatalyzed DPF	Platinum catalyst on filter surface
Continuously Regenerating Technology	Platinum oxidation catalyst upstream of filter
Fuel Borne Catalyst with uncatalyzed or lightly catalyzed DPF	**Platinum catalyst in fuel; engine, exhaust, soot and filter**

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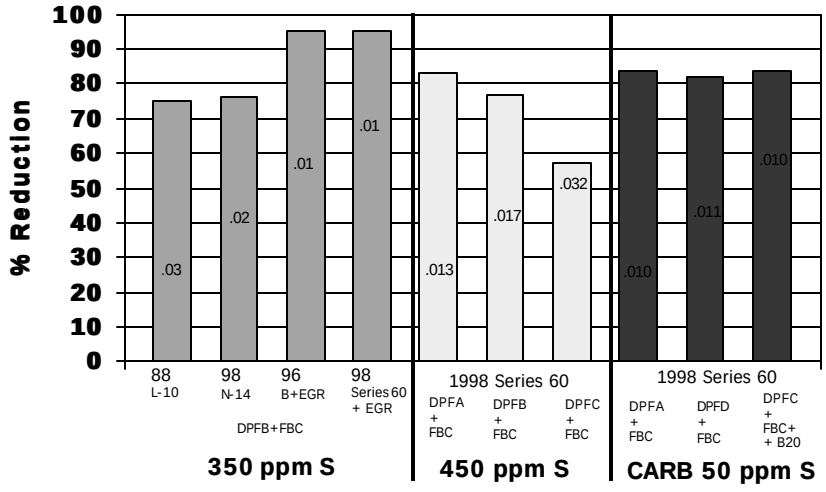
Particulate Reduction For FBC/DPF Combinations on Various Engines/Fuels

DPF A = Uncatalyzed Fiber Wound Filter
DPF B = Uncatalyzed Cordierite
DPF C = Lightly Catalyzed Cordierite
DPF D = Lightly catalyzed Cordierite
FBC = Platinum/Cerium Fuel Borne Catalyst



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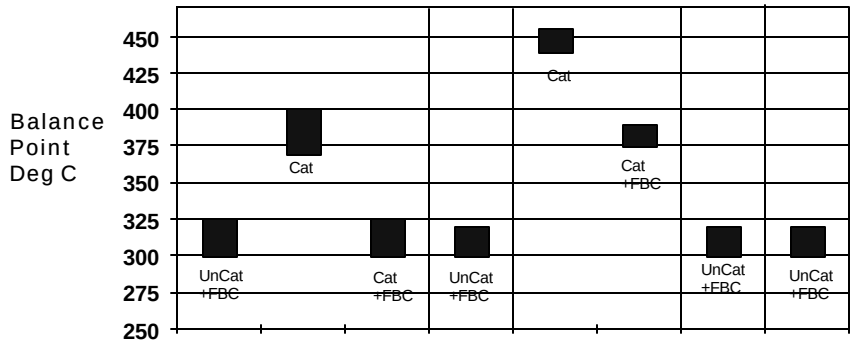
DPF Balance Points



Filter	Cordierite	Fiber	SiC	Fiber	SiC
Engine	B-96	B-98	L-10-88	B-94	Cat Loader(new)
Test	Dyno	Field	Dyno	Dyno	Field
Fuel	No.2	No.2	LSD	No.2	ULSD

Cat = Catalyzed DPF UnCat = Uncatalyzed DPF FBC = Fuel Borne Catalyst (Pt/Ce)

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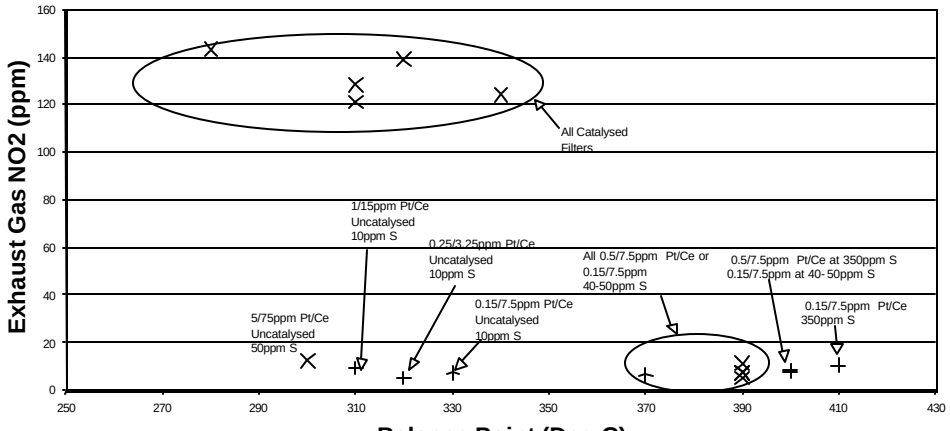
NO_2 Emissions From FBC/DPF System



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NO_2 Emissions From FBC/DPF System - Conclusions

- Pt/Ce FBC does not increase NO_2 emissions with uncatalyzed DPF even at 10 x overtreat
- Further work underway to match low NO_2 with good balance point
- May involve FBC with lightly precatalyzed DPF

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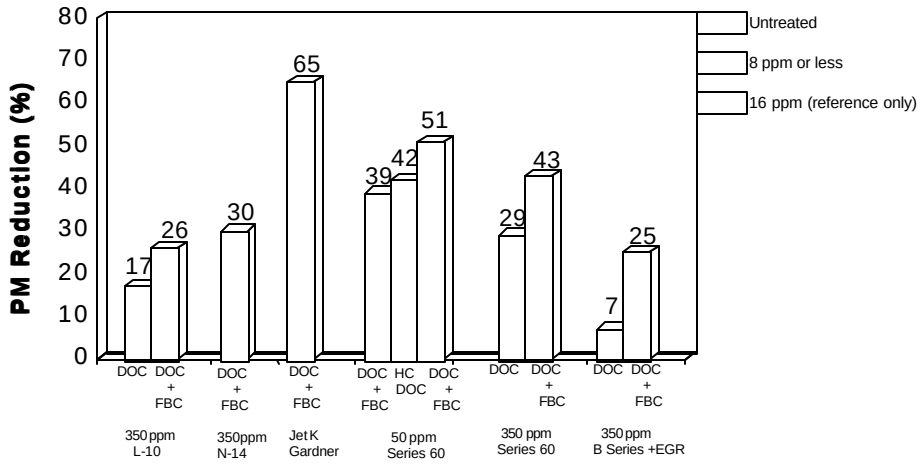
Performance of FBC/DOC

Combinations on PM Emissions
(Versus No.2D)



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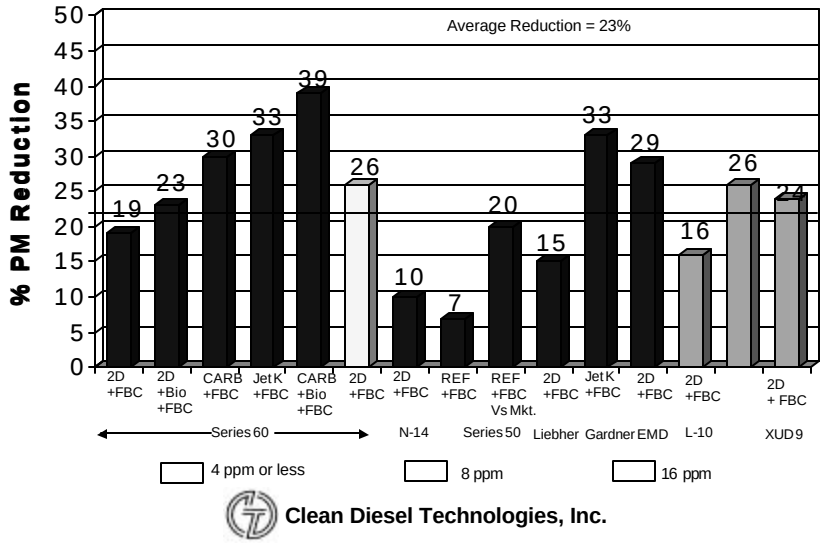
Performance of Bimetallic FBC

On PM Emissions
Versus No.2D



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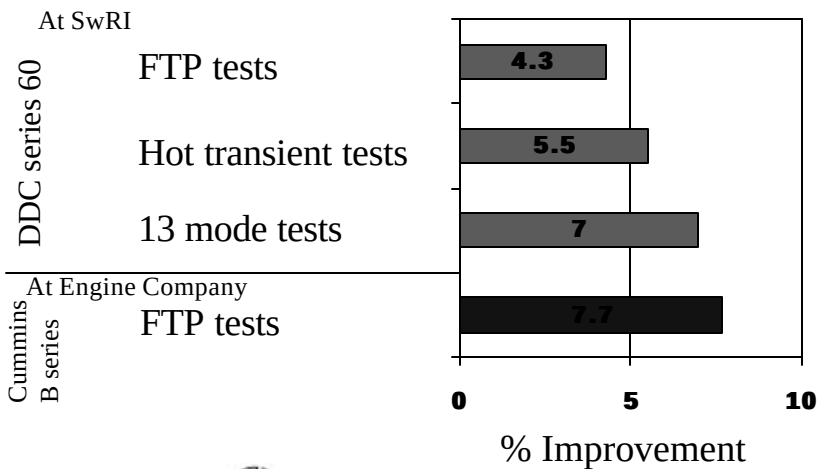
Fuel Economy
Engine Dynamometer Tests

Fuel measurements gravimetric, volumetric or carbon balance



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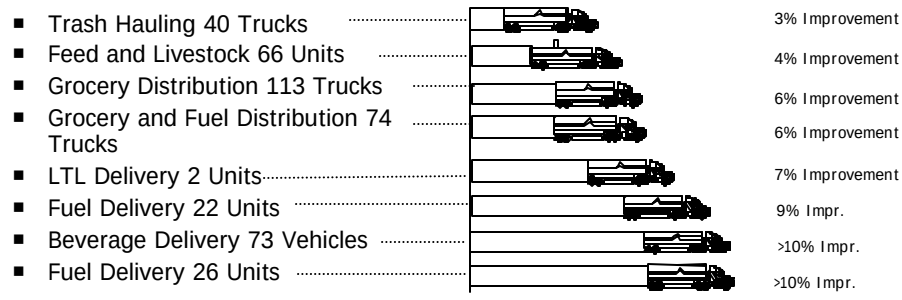
Platinum Plus® Fuel Economy

Results of 8 Fleets



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FBC Dosing Alternatives

- Manual addition to vehicle tank or fleet/field bulk tank
- Bulk fuel pretreatment by licensed fuel suppliers
- Automatic dosing at fuel pump or vehicle on-board dosing
- In use verification procedures
  - Fuel sample analysis for catalyst
  - Dosing system audits

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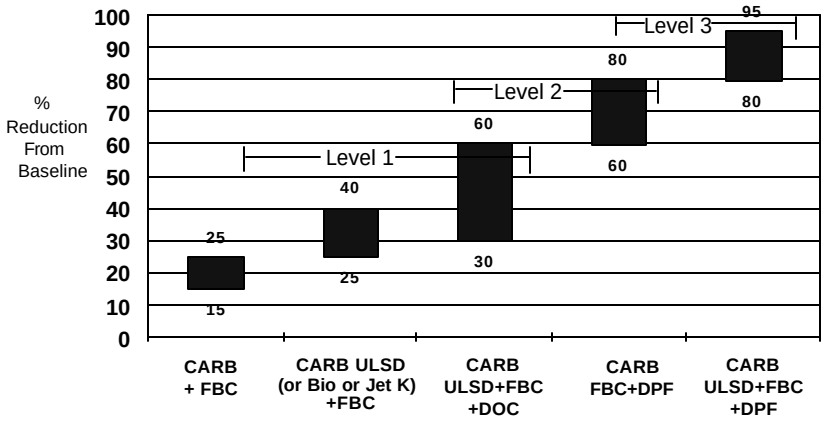
California Diesel PM Retrofit Control Options Using EPA Registered FBC



DOC = Lightly Catalyzed Oxidation Catalyst
DPF = Lightly Catalyzed or Uncatalyzed Filter
FBC = Platinum / Cerium FBC @ 8ppm

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Benefits of Bimetallic FBC/DPF System

- Ultra-low dose rate (4 to 8 ppm)
- Significant reductions in PM, HC, CO, PAH's and ultra-fines
- Combined with EGR or timing changes for 20-40% NOx reduction
- Uses lower cost uncatalyzed or lightly catalyzed filters
- Continuous regeneration at 280ºC-320 ºC
- MPG improvement helps offset FBC cost
- Fuel flexibility (15-350ppm S)
- Commercially available
- Planned submittal to CARB (1st quarter 2002)

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CDT's FBC/DPF California Commercialization Strategy

Licensed FBC Distributors

- California Fuel Marketers
  - Bulk Treatment
- Direct to Fleet
  - On Site Additization
- On Board Dosing

Filter Suppliers (Cordierite, Fiber Wound, Silicon Carbide)

- Clean Air Systems
- Lubrizol ECS
- Engelhard
- Fleetguard
- Others

Local Installation And Service

- Engine Distributors or Emission Control Companies
- Cleaire/Cummins West

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